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# REPORT OF THE COMMITTEE ON A TREATISE ON MARINE ECOLOGY AND PALEOECOLOGY

1949 - 1950

HARRY S. LADD, CHAIRMAN

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DIVISION OF GEOLOGY AND GEOGRAPHY

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1949 - 1950

Presented in preliminary form as Appendix E
at the Annual Meeting of the Division
April 29, 1950

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for list of previous reports.)

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# REPORT OF THE COMMITTEE ON

# TREATISE ON MARINE ECOLOGY AND PALEOECOLOGY

## INTRODUCTION

No formal meetings of the Committee were held during the year but the Chairman and Vice-Chairman Lohman held numerous conferences with members resident in Washington and carried on an extensive correspondence with other collaborators in the Treatise. Roger Revelle, Vice-Chairman for Oceanography, made several visits to Washington.

## TREATISE ON MARINE ECOLOGY AND PALEOECOLOGY

### GENERAL

A total of more than 100 separate assignments for sections of the Treatise have been made and more than one-fourth of these have been completed. A number of others will be finished in the near future but most of the remaining contributors do not expect to submit their manuscripts until April 1951, the deadline set 4 years ago. Contributions are being edited and integrated as received but it is doubtful if the Treatise will be ready to submit to the printer prior to 1952. As now visualized the work will consist of 2 volumes to be sold for a total of not more than 20 dollars. One publishing house has completed a market survey finding "almost universal approval" of the project.

One completed unit of the Treatise is included in the present report. This is an Annotated Bibliography on the Ecology of Marine Bacteria by Claude E. ZoBell. The Committee feels that Dr. ZoBell's paper is of particular interest because it summarizes the literature of a field that is not widely known among paleontologists. ZoBell's contribution includes only the more significant references that contain ecologic data and all are briefly annotated except in rare cases where the title clearly indicates the nature of the ecologic data. The introductory remarks are brief, summarizing the pertinent facts on the distribution of bacteria in the sea and on the part they play in its overall economy. The paper should be useful as a guide to others who are preparing similar bibliographic sections on other organic groups.

### CLASSIFICATION OF MARINE ENVIRONMENTS

The tentative classification of marine environments included in last year's Annual Report brought forth a number of critical comments and constructive suggestions. These illustrate clearly the wide differences of opinion that exist among ecologists and paleoecologists. All of the divergent views cannot be reconciled but certain changes in the arrangement offered last year will be made. For example, most of those who have criticised the tentative classification object strongly to the application of the word "littoral" to all environments to a depth of 200 meters and this usage should be abandoned. Suggestions for changes are still being received and all are being given serious consideration. Before the end of

1950 the Committee will submit a revised diagram to all workers who have commented on the original version. The Committee feels strongly that uniformity of usage is essential in the Treatise and it will make every effort to select a set of terms that appears to satisfy the experienced workers in the fields of ecology and paleoecology. Final decision will not be made until April of 1951, the deadline of the Treatise, and suggestions will be welcomed at any time before that date.

## CURRENT ACTIVITIES

### EASTERN UNITED STATES

Dr. W. H. Bradley of the U. S. Geological Survey has completed a preliminary study of the sediments and physical environment of the Sagadahoc Bay tidal flat near Georgetown, Maine. The flat and its surface sediments were mapped in detail and at one point the sediments were drained and a shallow pit excavated. Evidence of several sorts indicates that the surface of the flat as a whole is being built up. Dr. Bradley plans to do additional work in the same area during the summer of 1950.

Josiah Bridge and Jean M. Berdan of the U. S. Geological Survey are engaged in a study of the Paleozoic sediments encountered in some 45 deep wells drilled in the central and northern parts of Florida and adjoining parts of Georgia and Alabama, in an effort to determine the age of the formations encountered and something of the ecologic conditions existing at the time of their deposition.

Studies to date indicate that the bulk of the Paleozoic rocks penetrated are of Ordovician and Silurian age. Cambrian rocks have not been definitely identified, and no Paleozoic strata younger than Middle Devonian (?) have been found. The older units are chiefly sandstones with subordinate amounts of black, micaceous shales, the younger beds are composed almost entirely of soft, black, carbonaceous shale. No limestone beds have been found. The beds tentatively assigned to the Devonian consist of red and gray sandstones and shales contain fragments of plant fossils and are probably non-marine. The sandstones of the lower series are medium- to fine-grained, and both they and the shales interbedded with them contain large flakes of detrital mica. At many localities these beds contain zones up to 6 feet thick full of vertical worm borings separated by zones of equal thickness in which no borings are found. Linguloid brachiopods are the most abundant forms. The entire series seems to have been deposited in relatively shallow water. The younger black shales are extremely fine-grained, locally silty and lack the large flakes of detrital mica found in the older shales. Their faunas are a mixture of planktonic and benthic forms. The former include shells of nautiloids and of Hyolithus. Linguloids of several types are the most abundant of the benthic forms, but the presence of eurypterids and a form allied to Ceratiocaris suggests that some of the shales were deposited quite close to the shore line and probably in relatively shallow water.

The Chesapeake Bay Institute's new specially designed 58-foot research vessel, the MAURY, was launched in January 1950. The ship is being used to study the waters and marine life of Chesapeake Bay from the mouth of the Susquehanna River to the lower Capes of Virginia. Trial runs and several routine cruises were completed during the first half of 1950 and oceanographic data including bathythermograph records obtained from a number of stations. Cruise reports consisting of physical and chemical data in tabular form are sent to interested institutions and individuals as soon as chemical analyses are completed.

Director Donald W. Pritchard has been engaged in a study of the dynamics of estuarine waters. In a recent progress report he states:

> "An equilibrium condition has been found which appears to satisfy the required steady state pressure gradient in coastal plain estuaries similar to the Chesapeake Bay. It is observed that despite the run-off of fresh water into the Bay, there are periods when there is an apparent steady state distribution in salinities. This would indicate that there must be an in-flow of salt water from the ocean sufficient to maintain this steady state salinity distribution. This inflowing sea water must be returned to the ocean mixed with the outflowing water of river origin. This circulation appears to involve volumes of water several times the flow of fresh water into the Bay from rivers."

In the fall of 1949 a Marine Biological Laboratory was established by Florida State University. The Laboratory is located on the peninsula that forms Alligator Harbor about 40 miles south of Tallahassee. The purpose of the institution is threefold:

> "(1) To provide facilities for the training of students in marine sciences, especially at the graduate level; (2) to provide adequate facilities for an encouragement of research in marine sciences by staff members of both state universities, of other state institutions, and by visiting investigators from other states; (3) to carry on research closely related to the fishery industry of Florida and toward the goal of the development of unexploited marine resources."

As of July 1950 Director Harold J. Humm reports that the following research projects are underway:

> "1. A biological survey of the Apalachee Bay area designed to determine what are the common species of animals in the area, especially invertebrates, along with ecological notes on them.
>
> "2. An ecological study of the marine annelids of the intertidal zone of several different types of beaches.

"3. A study of the composition of the 'trash fish' of shrimp trawlers working out of Carrabelle and Apalachicola.

"4. A study of the physical properties of the agar or agaroid available from several species of seaweed that occur in great abundance in this area.

"5. A study of the distribution of the marine algae of the area."

In their study of the reefs off the coasts of the Carolinas, Drs. A. S. Pearse and Louis G. Williams have found 299 species of animals and 101 species of algae. With the help of specialists, all specimens have been identified and a final report is being prepared for publication.

Among the animals most groups (sponges, bryozoans, polychaetes, echinoderms, molluscs, amphipods, decapods, tunicates) had a distribution southward (166), but some (63) (hydroids, nemerteans, and 43 fishes) were widely distributed north and south, and a few (18) were largely from the north. Something more than a third of the species were estuarine and the rest were oceanic. Only one group (molluscs) showed a majority of species in both deep and shallow water, four (nemerteans, bryozoans, isopods, and amphipods) occurred most often on shallow reefs (12-20 ft.) and four (sponges, plychaetes, decapods, fishes) in deeper water. The 299 species of animals found were deep 102, shallow 95, and both 102. A third of the species were found off the coast of the Carolinas for the first time.

Of the 101 algae 24 species were collected in shallow water (12-20 ft.), 29 in deeper water (40-55 ft.), and 48 from both shallow and deep waters. Of these, 64 species were oceanic and 37 were estuarine and oceanic. In their latitudinal range 53 species were distributed from North Carolina southward, 29 north and south of North Carolina, and 12 were found in the Carolinas only. Nineteen species were reported for the first time from the Carolinas, two of these new to science.

Most of the reefs have a base of lower Miocene Trent marl. On this the algae form a thick encrustment or coating and in crevices sandstone is cemented together by calcareous and coralline algae, but on the whole algae contribute little as reef builders because there is too much current and wave action. Sessile snails and tubicolous annelids are significant reef builders. Their tubes form coatings 4 to 5 inches thick and are added to each year by living animals. Two clams (Saxicava and Lithophaga) bore into these coatings and into the Trent marl below.

Though none of the reefs studied were more than ten miles offshore and were still several miles from the Gulf Stream, the flora and fauna were found to be predominantly southern and oceanic in their relationships. Though madreporarian and gorgonian corals were present, they were apparently not as a rule significant contributors to the reefs.

Dr. George L. Clarke, of the Woods Hole Oceanographic Institution, reports as follows on current activities:

"One of my students has discovered that the length of day has an important influence on the reproductive activity of a fresh-water pulmonate snail. We very much suspect that we will find that other invertebrates, including some marine forms, may also show a photoperiodic response.

"Another student is making an intensive study of the life cycle of the sea scallop. Other students are carrying forward the analysis of the dynamics of production in marine areas. This includes the filtering rate of phytoplankton by zooplankton and the efficiency of the different steps in the food chain. At the same time field studies are being conducted in salt ponds on the seasonal cycles of growth of phytoplankton and zooplankton in relation to the hydrography and the chemical nutrients of the water."

## MIDDLE UNITED STATES

Benjamin H. Burma of the University of Nebraska is receiving support from the Office of Naval Research for a detailed study of the (estimated) 75 species of the foraminiferal genus Triticites in the United States. He believes that the results will enable him to formulate basic evolutionary and ecological principles which will be useful in the study of other Foraminifera that are used in the search for oil. Collecting in Iowa, Kansas and Nebraska is now almost completed.

Prof. Dale F. Leipper, Head of the Department of Oceanography at the Agricultural and Mechanical College of Texas, reports as follows on work in progress:

"Five research projects involving an annual expenditure of approximately $175,000 have been initiated. One of these is a systematic investigation of the oceanography and meteorology of the Gulf of Mexico sponsored by the Office of Naval Research, another a project in biological oceanography conducted at the laboratory of the Texas A. and M. Research Foundation at Grand Isle, Louisiana, and sponsored by a group of the major oil companies operating on the Gulf Coast, another a cooperative program with the Fisheries Biology Section of the U. S. Fish and Wildlife Service conducted from the oceanographic vessel, the ALASKA, and a fourth the work done under the Dow Research Fellowship in Chemical Oceanography. Finally, there is a study of marine pipeline problems being conducted for the United Gas Pipe Line Company of Shreveport, Louisiana."

For several years Dr. G. A. Cooper and associates of the U. S. National Museum have been studying the faunas and paleoecology of the rocks exposed in the Glass Mountains of Texas. The program is linked to the Permian Studies announced in the Journal of Paleontology, November, 1946, in which Drs. J. B. Knight, N. D. Newell, and several others are participating. Dr. Cooper reports:

"I visited the Glass Mountains in June and July, 1950. In early July I was joined by N. D. Newell of Columbia University and C. O. Dunbar of Yale for a few days' work on paleoecological interpretations. The special object of investigation was the Wolfcamp formation over which some differences of opinion have arisen. The existence of Wolfcamp rocks in the part of the mountains west of Iron Mountain had been questioned. This scepticism arose from a rapid shift of facies of the Wolfcamp formation between Leonard Mountain and the first mountain west of Iron Mountain about three miles away.

"The studies made during the spring and summer of 1950 indicate clearly that Wolfcamp rocks extend to Dugout Mountain at the west end of the Glass Mountains. West of Iron Mountain the Wolfcamp formation is composed of several hundred feet of coarse conglomerate containing some limestone layers abounding in the peculiar Permian reef brachiopod, Scacchinella, and the same forms that are associated with it at higher levels in the Hess formation.

"The Wolfcamp formation at its type section in the Wolfcamp Hills in the east central part of the Glass Mountains is composed of shales containing numerous limestone layers and masses. Some of the latter prove to be bioherms containing unusual colonial types of Permian brachiopods such as Orthotetinae, leptodids, Aulosteges and richthofenids. The enclosing shales, on the other hand, contain an assemblage more characteristic of high Pennsylvanian beds. Not only is this generalization true of the higher Wolfcamp it is also true of the Uddenites zone, a one hundred foot shaly band now assigned to the Gaptank formation. The bioherms of this division also contain such Permian types as Scacchinella and Aulosteges.

"To date these studies have not progressed far enough to permit definite conclusions on the exact age of these beds. Such conclusions must be based on the faunal studies which are now getting underway.

"The season's studies do indicate clearly, however, that the extension of the Wolfcamp formation west of Iron Mountain is a shore zone. The Scacchinella banks must have grown in and about coarse gravel beds. The type section of the Wolfcamp suggests sediments deposited somewhat farther from shore but, nevertheless, in shallow and vigorously moving waters. These sediments also contain some conglomerate but the section is mostly limestone and probably was produced by fragmentation of the biohermal masses."

Dr. Gordon Gunter, Acting Director of the Institute of Marine Science, reports that the station at Port Aransas is continuing its activities with some lessening of work on the oyster and an increase in work on the several species of peneid (commercial) shrimp. Plans for the future call for work on the ecology of the peneid shrimp.

In December 1949 the U. S. Geological Survey in cooperation with the Texas Bureau of Economic Geology began a study of the early Pennsylvanian reefs in west-central Texas and of the stratigraphy of the Pennsylvanian between the subsurface reefs and the outcrops in central Texas. Three phases of the project are now underway: the outcropping beds are being studied in detail in Brown County, Texas to determine the stratigraphic relations of units that can be traced into the subsurface; well samples taken by oil companies in Scurry and adjacent counties are being studied to find traceable horizons and to determine differences in lithology between the two sides of the reefs, and cores are being obtained from oil companies for paleontologic and lithologic study. As of July 1950 more than eight tons of three-inch core had been collected. Starting in the fall of 1950 a paleontologist will begin stratigraphic and ecologic studies of these cores.

In a progress report to the Office of Naval Research on investigations concerned with the measurement of paleotemperatures, Dr. Harold C. Urey and others report:

> "Since the summer of 1947 a group of us have been working on an isotopic paleotemperature scale. The problem proved to be a very difficult one and until December of 1949 we did not believe that we could measure the isotopic ratios of present day organically precipitated calcium carbonate precisely, and for this reason offered no papers for publication. During 1949 we succeeded in solving this problem to our satisfaction, and have accordingly prepared certain papers for publication." These include the following:
>
> The measurement of paleotemperatures and temperatures of the Upper Cretaceous of England, Denmark, and the Southeastern United States, by H. C. Urey, H. A. Lowenstam, S. Epstein, and C. J. McKinney.
>
> The carbonate-water isotopic temperature scale, by Samuel Epstein, Ralph Buchsbaum, Heinz Lowenstam and Harold C. Urey.
>
> A mass spectrometer for the measurement of small differences in natural abundances, by C. R. McKinney, J. M. McCrea, S. Epstein, H. A. Allen, and H. C. Urey.
>
> "In addition, Dr. Peter Baertschi of the University of Basel, Basel, Switzerland, investigated the isotopic abundance of $O^{18}$ in igneous and sedimentary rocks, and will publish this paper separately... Also, Dr. J. M. McCrea wrote a dissertation on inorganically precipitated calcium carbonate and its isotopic composition, and related problems...

On the isotopic chemistry of carbonates and a paleotemperature scale, by J. M. McCrea.

"The reports are very extensive and difficult to summarize in any brief way. However, we have shown that it is possible to construct a mass spectrometer adequate for our purpose, with a much higher precision for small differences in isotopic composition than has ever been attained before. We have shown that the isotopic composition of certain fossils has been retained over long periods of time at least since the Jurassic. We have been able to establish a temperature scale which so far as measurements are concerned should be accurate to about 1°C. All difficulties in connection with the use of this thermometer have been overcome with the exception of the variation in isotopic composition of the ocean, which is a serious difficulty. One method of avoiding this difficulty is under investigation. It is thought that it may be possible by using the isotopic composition of phosphates to eliminate the dependence on the isotopic composition of the water. Only further work can decide whether this is possible. We are also beginning work on the distribution of the hydrogen isotopes in nature, with the objective of using the abundance of the hydrogen isotopes to indicate the abundance of the oxygen isotopes because of the similar fractionation processes involved, namely, the evaporation of water. Also measurements have been made on the temperatures of the Cretaceous of England and the United States, and some interesting preliminary results have been secured."

## WESTERN UNITED STATES

K. O. Emery and R. E. Stevenson of the University of Southern California have completed a general report that attempts to synthesize the scattered and incomplete knowledge of estuaries, lagoons and marshes, their fauna and flora, sediments and water characteristics.

At the instigation of Clyde P. Ross, the U. S. Geological Survey has started a long-term study of stromatolites (fossil algae) known to occur in the pre-Cambrian Belt Series at many localities in the west. The excellent work already done on these fossils by Dr. Carroll Lane Fenton and Mildred Adams Fenton in Glacier National Park lead Dr. Ross to believe that such a study will be of real value in indicating the environment of deposition and--to a limited extent--in making stratigraphic correlations. Stephan C. Nordeng of the University of Wisconsin will undertake the work under the direction of Dr. Ross. Because few, if any, pre-Cambrian and Cambrian stromatolites show microscopic structure other than fine laminations a great deal of attention will be paid to the size, shape and growth habits of stromatolitic structures. Much of the work will of necessity be done in the field and extensive field sketching and photography will be required. Laboratory study of promising materials will be done with the assistance of Dr. J. Harlan Johnson of the Colorado School of Mines.

James Steele Williams and V. E. McKelvey of the U. S. Geological Survey report as follows on ecologic studies of the Phosphoria fauna:

> "Ecologic studies of the Permian Phosphoria faunas of the Northwestern United States were continued during 1950. Additional collections were made from stratigraphic sections measured or exposed by trenching in Idaho, Wyoming, Montana, and Utah. Collections were also made from rocks of similar age in eastern Nevada. Compilation of data and sorting of collections were done during the winter months in the paleontologic laboratories of the Geological Survey in Washington. New fish material was studied by David Dunkle of the U. S. National Museum, one of a number of specialists associated with the project."

## OUTSIDE THE CONTINENTAL UNITED STATES

The Arctic Research Laboratory at Point Barrow, Alaska, operated by the Johns Hopkins University under a contract with the Office of Naval Research has continued its varied studies of physical and biological phenomena in a little known environment. Director G. E. MacGinitie with Mrs. MacGinitie and others are primarily concerned with the distribution and ecology of Arctic marine organisms. Collections obtained by dredging operations such as those described in last year's report have been supplemented by others obtained from baited screen traps lowered through holes in the ice. The traps are inspected twice weekly, yielding snails, shrimps and amphipods. Large collections of marine organisms are being sent to various specialists for study and report.

Some of the difficulties encountered in doing ecological work in the Arctic are illustrated by the following statement from one of Dr. MacGinitie's Progress Reports:

> "During the month of June the salinity and temperature records of surface water have been taken bi-weekly instead of daily. The condition of the ice has made it increasingly difficult to get out to take samples, and because of so much melting ice the salinity of the surface water approaches that of fresh water. Even by using a six-foot arm with which to take the water sample, it was possible to reach only a few inches below the level of the ice, and hence not possible to get below the layer of fresh water. A ten-foot extension arm was made and with it water samples can be taken below the admixture of most of the fresh water with sea water."

Alfred R. Loeblich of the U. S. National Museum is carrying on taxonomic and ecologic studies of Recent Foraminifera at Point Barrow. During July 1950 seventeen bottom samples were examined. The samples were washed and the Foraminifera were picked, sorted and mounted. Four bottom samples were dredged from the mud zone off the Barrow base. Three foraminiferal faunal zones have been tentatively recognized but these must be verified by future collecting. The provisional zones are: (1) a zone in shallow

water near shore rich in Elphidium and a coarsely textured Reophax, (2) the mud zone characterized by small species of Foraminifera and by an abundance of Spiroplectammina and Virgulina and (3) beyond the mud a gravel zone characterized by abundant specimens of Elphidiella arctica. About 80 species of Foraminifera have been noted so far in the Barrow area.

A final report on the submarine geology and reefs of Bikini and nearby atolls in the Marshall Islands by K. O. Emery, J. I. Tracey, Jr. and H. S. Ladd is nearing completion and will be submitted for publication at the end of 1950. One phase of this study, the subsurface geology of Bikini as revealed by drilling has been completed by Tracey and the results submitted to Yale University as a doctor's thesis. Special reports on certain organic groups have also been completed: three of these deal with Foraminifera, both fossil and Recent, one by W. Storrs Cole, two by Miss M. Ruth Todd and Mrs. Rita Post, corals by J. W. Wells and fossil algae by J. Harlan Johnson.

At the U. S. National Museum F. M. Bayer has completed identifications of all alcyonarians obtained at Bikini while Dr. J. P. E. Morrison and associates have continued their work on the Recent mollusks.

Meanwhile, as noted below, the University of California has sent an expedition to the Marshall Islands. While there, one of the ships will dredge and attempt to take long submarine cores on the seamount that adjoins Bikini Atoll on the west. K. O. Emery, a Geological Survey representative on the expedition, will be in charge of this work and new data obtained will be incorporated in the final report on Bikini mentioned above.

The Scripps Institution of the University of California and the Navy Electronics Laboratory are cooperating in an oceanographic expedition to the mid-Pacific during the summer of 1950. Supplementary seismic refraction studies will be made at Bikini to obtain additional data on the location of basement rock beneath Bikini Island and satisfactorily resolve apparent differences between earlier seismic data and the results of the survey made by airborne magnetometer. Dr. Roger Revelle, Acting Director of the Scripps Institution, will be in scientific command of the expedition.

The Pacific Science Board of the National Research Council has sponsored and supported several investigations in Micronesia that are of interest to ecologists. These projects, as listed below, received generous financial support from the Office of Naval Research.

(1) Dr. Eugenie Clark of the American Museum of Natural History spent several months in Micronesia in 1949 making collections of reef fishes, particularly those of the Order Plectognathi. Collections were made in the Marshalls, Marianas and Western Caroline Islands. A special effort was made to obtain information and specimens of poisonous fishes. Poison assays are being made and meanwhile a mimeographed report on field activities has been issued by the National Research Council.

(2) Dr. M. W. de Laubenfels of the University of Hawaii made a reconnaissance survey of the sponge fauna of the Marshall, Caroline, Mariana and Palau Groups in 1949. Dr. de Laubenfels' work included a broad study of

shallow water environments in which he paid special attention to the ecological relationships controlling the field occurrences. Large collections of all types of sponges were made and a full report is now being prepared. A special report dealing with the possibilities of commercial sponge production, particularly in the Marshall Islands has been issued by the National Research Council.

(3) A comprehensive survey of a coral atoll is being carried out at Arno in the Southern Marshall Islands during the summer of 1950. Using an ecological approach, a group of scientists will study all the environmental factors that affect native life on coral atolls. In addition to the leader, Dr. Leonard Mason, an anthropologist of the University of Hawaii, the group includes: Dr. R. W. Hiatt, University of Hawaii, marine ecologist; Dr. J. T. Marshall, University of Arizona, vertebrate ecologist; Dr. J. W. Wells, Cornell University, geologist; Earl Stone, Cornell University, soil scientist; Doak C. Cox, Hawaiian Sugar Planters' Association, hydrologist; Donald Anderson, botanist; Gerald G. Wade, University of Hawaii, geographer; and Dr. Ira LaRivers, University of Nevada, entomologist.

In outlining his part of the program Wells pointed out that Arno Atoll is especially suited for coral reef investigations because:

(1) Though Bikini and other atolls in the Northern Marshalls have been intensively studied, Arno and its neighbors in the southern half of the group are almost unknown.

(2) Arno's form differs from that of a "typical atoll" and the relation of its "horns" to prevailing winds and currents is not what might be expected.

Wells plans to study the geomorphology of the atoll in relation to winds and currents and the structure of the existing coral reefs. Collections of corals and other organisms will be made from the reefs and from the lagoon. Dredging equipment for the collection of bottom samples and invertebrates has been furnished by the U. S. National Museum.

The U. S. Geological Survey, in cooperation with the Corps of Engineers, U. S. Army, is continuing its program of mapping in the Pacific Islands under the leadership of S. K. Neuschel. Detailed field mapping and reef studies on the island of Tinian in the Marianas Islands were begun in November 1949 by a party headed by Harold W. Burke. As was done on Saipan, the distribution of various rock facies as associated with the growth and destruction of reefs is being mapped. This same method will be applied on the other southern Marianas Islands, Rota and Guam, which will be mapped after Tinian is finished.

The Geological Survey has received a large collection of fossils from Guam. These were collected during the course of geological mapping and exploratory drilling by the Pacific Island Engineers, the contract engineer to the Officer in Charge of Naval Construction, Guam. The Survey has also received as a transfer from the Navy a set of drill cores taken on Guam totaling about 40,000 feet. These cores are at present housed on Guam where

they will be studied during the course of geological mapping in the Marianas by the Survey. The significant portions of the core material will eventually be placed in the custody of the U. S. National Museum and be studied along with cores from Kita Daito Shima and other Pacific Islands.

In addition to the studies of collections from Bikini already mentioned, work was continued on geologic reports based on field work in Saipan, Yap, Palau, and Okinawa. W. Storrs Cole and John W. Wells are studying fossil collections--Foraminifera and corals respectively--obtained from several of these areas.

A special study of calcareous algae, including their distribution, geologic work in building limestones, and ecologic relationships and part in the construction of both fossil and present-day reefs is being made by Dr. J. Harlan Johnson. Field work was done on Saipan, Guam and the Palau Islands where extensive collections of limestones and modern and fossil calcareous algae were made. The material is being studied by Dr. Johnson at the Colorado School of Mines and reports will be prepared. Dr. Johnson's research brought him to Japan where numerous discussions were held with Watara Ishijima, Rikkyo University, Tokyo, the outstanding Japanese authority on fossil calcareous algae, and Sokiti Segawa, Kyushu University, the Japanese expert on modern coralline algae. The collections of the Japanese and their publications were examined in detail and their present work was reviewed to consider its value and use to workers in other countries. The most important publications of Ishijima and Segawa, written in Japanese, were obtained and translated and are now available for examination in the U. S. Geological Survey library.

Systematic study of the fossil mollusks collected by members of the U. S. Geological Survey on Okinawa was continued by F. Stearns MacNeil, who reports:

> "The total number of species involved will run close to 800. These can be divided roughly into three main facies faunas; 1) a deep water fauna, probably over 200 fathoms of depth, of about 300 species, 2) a shallow water clastic sediment fauna, probably mostly less than 50 fathoms in depth, of between 300 and 400 species, and 3) a limestone fauna, in part coral reef, of about 100 species.
>
> "The deep water fauna contains such interesting genera as Teremachia, Thatcheria, and Samarangia as well as several relict lower Tertiary genera that are being found in the upper Tertiary for the first time. A significant percentage of the fauna consists of species or close relatives of species that heretofore have been recorded only by deep sea expeditions in the western and Indo-Pacific, or are to be found as undescribed species in the collections obtained by the Albatross in the Philippines. The deep water fauna is not the first fossil fauna of this type to be described from the western Pacific but it certainly will be the largest; the fact that an upper Miocene age can probably be ascribed to it makes it the more interesting.

"The shallow water clastic sediment fauna, although large, is mainly a duplication of the already described fauna of the Byoritzu beds of Formosa, and is probably of the same age.

"The oldest part of the limestone fauna is equivalent to the shallow water clastic sediment fauna, and likewise contains many elements of the Byoritzu fauna. Both of these facies faunas are regarded as being of Pliocene age.

"The youngest part of the limestone section rests unconformably on the lower part and contains a much greater amount of coral; it apparently was predominantly a reef facies. The species are identical with living forms, and the beds are regarded as Pleistocene in age."

Delos Flint and Raymond Saplis state that a preliminary engineering geology map of Okinawa for the use of the Armed Forces has been published in Tokyo—scale 1:100,000. The preparation of a comprehensive report on the applied aspects of the geology of Okinawa should be completed by June 1951. Prior to the appearance of that report, Flint and Saplis plan to publish a summary of the geology of Okinawa.

Raymond Saplis is studying the lithologic variations of the reef-type limestones of Okinawa, giving special attention to the problem of cementation of the Ryukyu limestone. Field evidence has shown that the limestones classed as Ryukyu were deposited as unconsolidated or poorly consolidated debris and became lithified only after exposure to the weather. The distribution of well-cemented and poorly-cemented limestone has had a great influence on the physiographic development of the limestone islands. Many features formerly thought to be raised reefs are now known to be zones or areas that were more tightly cemented and subsequently brought into relief by weathering. The process of cementation is believed to be a recrystallization process caused by alternate wetting and drying, though chemical composition, grain size, and permeability of the original sediments seem to have a marked effect in causing more rapid and complete cementation in some beds. The factors which apply to the natural cementation of limestones will also apply to the selfsetting "coral" used by the engineers throughout the western Pacific for airfield and road construction. It is hoped that this study will determine some of the controlling factors in the process of cementation and perhaps define the characteristics of self-cementing limestones.

A collection of more than 1,000 mega and micro fossils of Formosa was acquired by Arnold C. Mason during a geologic field reconnaissance on that island. The collection has been sent to the U. S. Geological Survey in Washington and will be preserved and available for study in the U. S. National Museum.

Work was continued by Helen L. Foster on an annotated bibliography of geologic literature on the islands of the Trust Territory, the Ryukyus, and Formosa. All literature that can be located which was published by the Japanese on paleoecology and related geologic subjects will be included.

Translation of Japanese geologic literature on the islands under former Japanese mandate, and other areas of special interest in the Pacific, continued. The translations can be examined in the U. S. Geological Survey Library.

Operation Cabot, a multiple ship survey to obtain information on the behavior of the Atlantic Ocean's Gulf Stream, was carried out in June 1950 as a cooperative project between the Woods Hole Oceanographic Institution, the Hydrographic Office of the U. S. Navy, the Canadian Research Establishment, the U. S. Fish and Wildlife Service, and the Scripps Institution of Oceanography. A total of six vessels participated, obtaining information simultaneously over a stretch of ocean measuring 1500 miles. The Gulf Stream is known to meander widely between Cape Hatteras and the tail of the Grand Banks, off Newfoundland. The meanders move north and south at rates of one or two miles per day, sometimes breaking off to form large eddies. The overall pattern is so complex that one vessel cannot obtain a plot of the oceanic circulation at any one time. The six vessels participating in Operation Cabot sailed easterly at spaced intervals following along the stream, obtaining simultaneous observations on the location and spread of the Stream. In a second phase of the operation the ships sailed north and south along selected longitudes, stopping every two hours for temperature and salinity observations down to depths of 6,000 feet. In a third phase the movements of meanders and eddies were investigated.

## RECENTLY PUBLISHED PAPERS

Most of the papers listed below appeared during the year ending May 1, 1950.

### GENERAL

Allee, W. C., Emerson, Alfred E., Park, Thomas, Park, Orlando, and Schmidt, Karl P.
Principles of Animal Ecology, pp. 1-837, W. B. Saunders, Phila., 1949, $14.00.

Anderson, Judson L. and others
Cretaceous and Tertiary subsurface geology; the stratigraphy, paleontology and sedimentology of three deep test wells on the Eastern Shore of Maryland, Bull. 2 State of Md., Dept. of Geology, Mines and Water Res., pp. 1-456, figs. 30, pls. 39, 1948.

Bernard, Francis
Recherches préliminaires sur la fertilité marine au large d'Alger, Cons. Perm. Internat. Explor. Mer. Jour. Conseil., vol. 15, pp. 260-267, 1948.

The density of protista per liter is 3 or 4 times larger than off Monaco in the deep euphotic zone. The Calcioflagellates represent 88% of the mean volume of phytoplankton. In the upper layers and the aphotic zone the fertility seems to be equal to or lower than off Monaco. Annual production as shown by the fisheries is 4 to 5 times richer than in the northern Mediterranean. This is probably related to the abundance of phosphates in the middle layer, since light and nitrates rarely fall to low values. An evaluation of potential fertility is made. The high oxygen content is possibly one cause of the dominance calcareous flagellates. (Gordon Gunter).

Birshtein, IA. A.
Godovye izmemeniia bentosa severnogo Kaspiia, (Annual variations in the benthos of the northern part of the Caspian Sea), Zoologicheskii Zhurnal, vol. 24, pp. 133-147, 1945.

Within the limits of the northern part of the Caspian Sea five main complexes of sea-bottom fauna may be differentiated: (1) the complex of the deltas and fore-deltas, (2) the complex of the soft grounds of the slope, (3) the complex of the hard grounds, (4) the complex of the Ural furrow, and (5) the complex of the halophile species. The biomass of the northern Caspian is distributed extremely unevenly. (Gordon Gunter).

Bond, Geoffrey
The Lower Carboniferous reef limestones of Cracoe, Yorkshire, Quart. Jour. Geol. Soc. London, vol. 105, No. 418, pp. 157-188, 1950.

Brongersma-Sanders, Margaretha
The importance of upwelling water to vertebrate paleontology and oil geology, Verh. konkl. Nederlandsch Akad. v. Wetenschappen afd. Natuurkunde, vol. 45, No. 4, pp. 1-112, 1948.

Chapman, V. J.
The marine algal communities of Stanmore Bay, New Zealand (Studies in Inter-tidal Zonation 1), Pacific Science, vol. 4, No. 1, pp. 63-68, 1950.

Cline, L. M. and Burma, B. H.
Paleoecological study of the Pennsylvanian Exline limestone of Iowa and Missouri, (abstract), Bull. Geol. Soc. Amer., vol. 60, No. 12, pt. 2, pp. 1180-81, 1949.

Coleman, John S.
The sea and its mysteries: An introduction to the science of the sea, London: G. Bell and Sons; New York: British Book Centre, 285 pp., 1950. 12s. 6d. net.

Doeglas, D. J., Koning, A., and Germeraad, J. H.
Tidal-flat environment, (abst.), Bull. Geol. Soc. Amer., vol. 60, No. 12, pt. 2, pp. 1882-83, 1949.

Durham, J. Wyatt
Pacific Coast Tertiary marine climates, (abstract), Bull. Geol. Soc. Amer., vol. 60, No. 12, pt. 2, p. 1884, 1949.

Ebling, F. J., Kitching, J. A., Purchon, R. D., and Bassindale, R.
The ecology of the Lough Ine Rapids with special reference to water currents, II, The fauna of the Saccorhiza canopy, Jour. Animal Ecol., vol. 17, pp. 223-224, 1948.

The bed of the Lough Ine Rapids is covered by large laminarian seaweeds, mainly S. bulbosa. The fronds form a dense canopy, which has a typical fauna associated with it. A study has been made of the speed of the water current at the level of the canopy throughout the tidal cycle (12.5 hrs.) at a series of selected stations. The total lengths of water-columns passing and the maximal speed of the current at each station are given. The various stations range, in maximal speed of current, from a very low value up to 2.5 m./sec. An investigation has been made of the distribution of animals associated with the canopy. This investigation comprises both general observations made throughout the Rapids area and a detailed study of samples of Saccorhiza collected at the stations. Of the animals studied 6 species (3 polyzoans and 3 gastropods) were confined to situations where they were exposed to weak currents only, that is, on the fronds of Saccorhiza at stations of quiet water and in some cases in the shelter of the crenulated margins ("frills") of the stipes at stations of stronger current. Two species (the polyzoan Membraniport membranacea and the limpet Patina pellucida) favored moderate current and were

less abundant in weak or strong current. Two species (the amphipod Fassa falcata and the hydroid Tubularia bellis) favored proximity to strong current but not direct exposure to it. In experiments with the gastropod Gibbula cineraria it was shown that the adult animal was washed off Saccorhiza by strong currents. (Gordon Gunter).

Edmondson, Charles Howard
Seashore treasures. Palo Alto, Calif.: Pacific Books, 144 pp., 1949. (Illustrated.) $3.50.

Elton, Charles
Population interspersion, An essay on animal community patterns, Jour. Ecol., vol. 37, pp. 1-23, 1949.

The ultimate goal of an ecological survey is an attempt to discover the main dynamic relations between populations living in an area. The habitat is a mosaic of centers of different kinds, centers of action in which interspersion between populations tends to be complete, and ecological dynamic relations at their strongest. The population of each species of animal tends to a periodic contouring, not to a general distribution of density at random. There may be visualized, on any area, an ecosystem composed of comparatively limited minor centers of action, each having certain distinctive characteristics that are reflected in their communities, and which have a considerable amount of inter-change by lateral and vertical movements. There should be a large number of studies on these small component communities carried out in such a way that the data can eventually be linked with similar studies. Ecologists, also, need some comprehensive principles for classifying habitats, based on these patterns and their component parts. Population interspersion is a subject which involves equally all the present theories of demology as well as the arrangement of communities, because it is of the nature of animal communities, and therefore of their populations, not to be evenly distributed, though the unevenness of density is itself subject to ecological laws. (Gordon Gunter).

Evans, Ronald G.
The intertidal ecology of rocky shores in south Pembrokeshire, Jour. Ecol., vol. 37, pp. 120-139, 1949.

Faul, H. and Roberts, W. A.
New fossil footprints from Colorado, (abstract), Bull. Geol. Soc. Amer., vol. 60, No. 12, pt. 2, p. 1886, 1949.

Frizzell, Don L., and Anderson, I. J.
Diastems in the Pecan Gap chalk of Travis Co., Tex., Jour. Sed. Petrology, vol. 20, No. 1, pp. 55-59, 1950.

Hardenberg, J. D. F.
Onderzoek en problemen der Indische zeeën. (Investigation and problems of the seas of the Indies.) Chron. Nat., vol. 104, pp. 337-344, 1948.

Harvey, H. W.
On the production of living matter in the sea off Plymouth, Jour. Mar. Biol. Assoc., United Kingd., vol. 29, No. 1, pp. 97-137, 1950.

Henson, F. R. S.
Cretaceous and Tertiary reef formations and associated sediments in Middle East, Bull. Amer. Assoc. Petroleum Geol., vol. 34, No. 2, pp. 215-238, 1950.

Hills, E. Sherbon
Shore Platforms, Geol. Mag., vol. LXXXVI, No. 3, pp. 11-152, 3 plates, 1949.

Holme, N. A.
The bottom fauna of Great West Bay, Jour. Mar. Biol. Assoc., United Kingd., vol. 29, No. 1, pp. 163-183, 1950.

Howell, B. F. and Stubblefield, C. J.
A revision of the fauna of the North Welsh Conocoryphe viola beds implying a Lower Cambrian age, Geol. Mag., vol. 87, No. 1, pp. 1-16, 1950.

Hutchinson, G. Evelyn
Circular causal systems in ecology, Ann. New York Acad. Sci., vol. 50, pp. 221-246, 1948.

The aspect of ecology considered regards primarily the study of the conditions under which groups of organisms exist. The fact that in nature circular paths often exist which tend to be self-correcting within certain limits, but which break down producing violent oscillations when some variable in the system transgresses limiting values is the basis of the discussion. The analysis of such circular systems is approached from two angles: the biogeochemical and the biodemographic approach. Under the biogeochemical aspect, the carbon cycle in the biosphere and the phosphorous cycle in inland lakes are considered. Under the biodemographic aspect, unlimited and restricted growth is analysed mathematically in which the concept of competition and balance of nature, prey-predator relationships, oscillation and natural selection, and the concept of saturation are considered. (Gordon Gunter).

Imbt, Robert F. and McCollum, S. V.
Todd Deep field, Crockett County, Texas, Bull. Amer. Assoc. Petroleum Geol., vol. 34, No. 2, pp. 239-262, 1950.

Johnson, J. Harlan
An introduction to the study of organic limestones, Quart. Jour. Colorado Sch. Mines, vol. 44, No. 4, pp. 1-139, 1949.

Johnson, M. R. W.
The fauna of the Rhaetic beds in South Nottinghamshire, Geol. Mag., vol. 87, No. 2, pp. 116-120, 1950.

Kamps, L. F.
Enige gegevens over de sedimentatie in het Waddengebred ten Noorden van de Provincie Groningen, Koninklijk Nederlandsch Aardrijkskundig Genootschap, Tweede Reeks, Deel LXVII, No. 3, pp. 369-373, 1950.

Ketchum, Bostwich and Keen, Jean
Unusual phosphoric concentrations in the Florida "Red Tide" sea water, Jour. Mar. Res., vol. 7, No. 1, pp. 17-21, 1948.

Krumbein, W. C., Sloss, L. L., and Dapples, E. C.
Sedimentary tectonics and sedimentary environment, Bull. Amer. Assoc. Petroleum Geol., vol. 33, No. 11, pp. 1859-1891, 1949.

Ladd, Harry S.
Recent reefs, Bull. Amer. Assoc. Petroleum Geol., vol. 34, No. 2, pp. 203-214, 1950.

Ladd, H. S. and Tracey, J. I., Jr.
The problem of coral reefs, Sci. Monthly, vol. 69, No. 5, pp. 297-305, 1949.

Lejeune, P. H. de Oliveira
Distribuicão geográfica da fauna da Baía Guanabara, Mem. Inst. Oswaldo Cruz, vol. 45, pp. 709-735, 1947.

The author studied the horizontal and vertical distribution of most common part of the flora and fauna of the Bay of Guanabara at Rio de Janeiro. The eulittoral, poly-, meso and oligohaline regions were localized and studied, and a preliminary chart of their distribution presented. (Gordon Gunter).

Link, Theodore A.
Theory of transgressive and regressive reef (broherm) development and origin of oil, Bull. Amer. Assoc. Petroleum Geol., vol. 34, No. 2, pp. 263-294, 1950.

Longwell, Chester R., Moore, R. C., McKee, E. D., Muller, S. W., Spieker, E. M., Wood, H. E. 2d., Sloss, L. L., Krumbein, W. C., and Dapples, E. C., et. al.
Sedimentary facies in geologic history, Geol. Soc. Amer., Mem. 39, pp. 1-171, 1949.

Lowman, S. W.
Sedimentary facies in Gulf Coast, Bull. Amer. Assoc. Petroleum Geol., vol. 33, No. 12, pp. 1939-1997, 1949.

Morales Macedo, Carlos
La vida en los mares del Perú, Bol. Mus. Hist. Nat. "Javier Prado", vol. 10, pp. 3-31, 1946.

The oceanography, geophysics, ecology, and plant and animal life in the Pacific Ocean adjacent to the coast of Peru are described in general terms.

Niino, Hiroshi
Bottom deposits at the mouth of Wakasa Bay, Japan, and on the adjacent continental shelf, Jour. Sed. Petrology, vol. 20, No. 1, pp. 37-54, 1950.

Pettersson, Hans
Submarine geology: Swedish Deep Sea Expedition (Abstract), Bull. Geol. Soc. Amer., vol. 60, No. 12, pt. 2, p. 1914, 1949.

Pettersson, Hans
The chronology of the ocean floor, The Advancement of Science, vol. 7, No. 25, pp. 57-62, 1950.

Phleger, Fred B.
Submarine geology and Pleistocene research, Bull. Geol. Soc. Amer., vol. 60, No. 9, pp. 1457-1462, 1949.

Pugh, W. E.
Bibliography of organic reefs, bioherms, and biostromes, Seismograph Service Corp., Tulsa, Okla., pp. 1-139, 1950.

Rich, John Lyon
Flow markings, groovings, and intra-stratal crumplings as criteria for recognition of slope deposits, with illustrations from Silurian rocks of Wales, Amer. Assoc. Petroleum Geol., vol. 34, No. 4, pp. 717-741, 15 figs., 1950.

Richards, Horace G.
Postglacial marine submergence of Arctic North America with special reference to the Mackenzie delta, Proc. Amer. Phil. Soc., vol. 94, No. 1, pp. 31-37, 1950.

Rigg, George B. and Miller, Robert C.
Intertidal plant and animal zonation in the vicinity of Neah Bay, Washington, Proc. Calif. Acad. Sci., 4th Ser., vol. 26, No. 10, pp. 323-351, 1949.

The vertical distribution of marine algae and marine invertebrates in or adjacent to the intertidal zone at certain localities in the vicinity of Neah Bay in the extreme northwest corner of Washington is reported. Zonation is regarded as a resultant of two primary factors, which are in fact reciprocals of each other: (A) Organisms of the upper littoral have an optimum vertical range that is determined by a variety of conditions, among which are food supply; illumination; degree of resistance to desiccation when exposed to air and sunshine, and to endosmosis when exposed to rain; and adaptability to survival under the pounding of heavy surf. (B) Organisms characteristic of a given vertical range often survive in limited numbers above or below the level regarded as optimum. It would appear that in the absence of competition such organisms could successfully occupy much wider vertical ranges. Their apparent restriction to a narrow belt is due primarily to competion from other organisms better adapted to the vertical ranges immediately adjacent. (Gordon Gunter).

Sears, Paul B.
Integration at the community level, Amer. Scientist, vol. 37, pp. 235-242, 1949.

The value of qualitative and quantitative processes in establishing the community are discussed with an evaluation of the various concepts instrumental to the study of the relation between life and environment. Ecological studies now draw heavily upon modern genetics, growth regulators, and thermodynamics as well as other biotic factors in establishing the community. (Gordon Gunter).

Shepard, Francis P.
Terrestrial topography of submarine canyons revealed by diving, Bull. Geol. Soc. Amer., vol. 60, No. 10, pp. 1597-1612, 1949.

Shorygin, A. A.
Izmeneniia kolichestva i sostava bentosa severnogo Kaspiia v 1935-1940 gg. (Changes in the quantity and composition of the benthos in the northern part of the Caspian Sea in 1935-1940.) Zoologicheskii Zhurnal, vol. 24, pp. 148-160, 1945.

Between 1929 and 1940 the level of the Caspian Sea sank by almost 2 m. This greatly affected its hydrology and the quantity, distribution, and composition of its fauna, especially the benthos. The changes were especially marked in the shallow northern part of the sea. By means of large scale investigations, made with the help of a Petersen dredge in 1935, 1937, 1938, and 1940, it was established that during this period the amount of benthos in the northern Caspian diminished greatly. On the other hand, the numbers of a few definite forms (Cardium edule, Mytilaster lineatus, Oligochaeta, Polychaeta) greatly increased. The analysis of the dependence of the distribution of mollusks on salinity showed that those species which increased during this period are among the most halophile, while the greatest quantitative decrease was experienced by the more fresh-water loving forms. It seems possible, therefore, to presume that the changes in the quantity and composition of the benthos were caused mainly by changes in salinity, which have been very considerable, and consisted chiefly in a marked salinization of the eastern part of the northern Caspian. The areas of distribution of halophile organisms have greatly expanded during the periods studied, while those of the fresh-water forms have shrunk. However, not all the changes in the biomass can be explained by the changes in salinity, since in the southern part of the northern Caspian some halophile species also showed a numerical decrease. The causes of this are not quite clear and consist presumably in the impoverishment of the bottom water layers in $O_2$ in 1936. The explanation of the increase in numbers of Polychaeta and Oligochaeta is to be seen in the increase of the amount of fresh organic matter in the bottom deposits due to the death of immense numbers of the more fresh-water organisms. (Gordon Gunter).

Smith, F. G. Walton
Probable fundamental causes of red tide off the west coast of Florida, Quart. Jour. Florida Acad. Sci., vol. 11, pp. 1-6, 1948 (1949).

Gymnodidium brevis has been established as the cause of the red tide. Other species of planktonic organisms increased in numbers at the same time. Submarine deposits of nitrates and phosphates, suddenly transported to a wide ocean area by shifting bottom currents could have provided a milieu suitable for an extraordinary bloom of planktonic organisms. The transport of these nutrients from rivers is not likely as shown by prevailing currents. (Gordon Gunter).

Stephenson, T. A. and Stephenson, Anne
Life between tidemarks in North America, Endeavour, vol. 9, No. 33, pp. 11-17, Jan. 1950.

Stoyanow, Alexander
Lower Cretaceous stratigraphy in southeastern Arizona, Geol. Soc. Amer., Mem. 38, pp. 1-169, 1949.

Tolstoy, Ivan and Ewing, Maurice
North Atlantic hydrography and the mid-Atlantic Ridge, Bull. Geol. Soc. Amer., vol. 60, pp. 1527-1540, 1949.

Twenhofel, W. H.
Characteristics and geologic distribution of coral and other organic reefs, World Oil, vol. 129, No. 3, pp. 61-64, 1949.

Twenhofel, W. H.
Coral and other organic reefs in geologic column, Bull. Amer. Assoc. Petroleum Geol., vol. 34, No. 2, pp. 182-202, 1950.

Urey, Harold C., Epstein, Samuel, Lowenstam, Heinz A., and McKinney, Charles R.
Paleotemperatures of the Upper Cretaceous (abst.), Science, vol. 111, pp. 462-463, 1950.

Urry, William D.
Radioactivity of ocean sediments VI. Concentrations of the radio-elements in marine sediments of the southern hemisphere, Am. Jour. Sci., vol. 247, No. 4, pp. 257-275, 1949.

Waring, W. W., and Layer, D. B.
Devonian dolomitized reef, D3 Reservoir, Leduc Field, Alberta, Canada, Bull. Amer. Assoc. Petroleum Geol., vol. 34, No. 2, pp. 295-312, 1950.

Weaver, Charles E., Geology of the Coast Ranges immediately north of the San Francisco Bay region, Calif., Geol. Soc. Amer., Mem. 35, pp. 1-242, 1949.

Whiteley, George C. Jr., Burbanck, William D., and Pierce, Madeline E.
A preliminary study of the factors influencing the distribution of bottom fauna in two narrow arms of Buzzards Bay, (abstract), Biol. Bull., vol. 97, p. 250, 1949.

Wilson, W. B.
Reef definition, Bull. Amer. Assoc. Petroleum Geol., vol. 34, No. 2, p. 181, 1950.

Wiseman, J. D. H. and Ovey, C. D.
Recent investigations on the deep-sea floor, Proc. Geological Assoc., vol. 61, pt. 1, pp. 28-84, 1950.

Yañez, Parmenio
Información preliminar sobre el ciclo anual del plancton superficial en la Bahia de Valparaiso, Rev. Biol. Marina, vol. 1, pp. 57-59, 1948.

The plankton of Valparaiso Bay, upon which only brief reports have been made previously, was investigated in respect to seasonal distribution. Nine genera of diatoms in the phytoplankton showed periodic cycles of increase and decrease in abundance. Four periods were recognized: a long period of increased production in spring and early summer, a long period of low production in autumn and early winter, a short pulse in July, and a short period of low productivity in Aug. Zooplankton begins to increase in Aug. after a brief decline and continues to a maximum in Nov. during which time there is an abundance of larval stages of many forms. In February the zooplankton is low in productivity but about that time there is another cycle of larval development which reaches its maximum in April. May and June again show a low zooplankton biota, but in July there is a short pulse, followed by a conspicuous drop in production. (Gordon Gunter).

Yañez, Parmenio
Organización actividades de la estación de biología marina de Montemar, Rev. Biol. Marine, vol. 1, pp. 5-18, 1948.

The history, description, and planned program of this new marine biological station a branch of the Univ. of Chile, is outlined.

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Hydrostatic pressure as a factor which influences the distribution of marine microorganisms in the sea, (abstract), Bull. Ecol. Soc. America, vol. 30, p. 61, 1949.

PLANTS

Barghoorn, Elso S.
Degradation of plant remains in organic sediments, Botanical Museum Leaflets, Harvard University, vol. 14, No. 1, pp. 1-20, 1949.

Boden, Brian P.
The diatoms collected by the U.S.S. Cacopan in the Antarctic in 1947, Jour. Mar. Res., vol. 8, No. 1, pp. 6-13, 1949.

Copenhagen, W. J. and Copenhagen, L. D.
Variation in the phytoplankton of Table Bay, October 1934 to October 1935, with a note on the calorific value of Chaefoceros species, Trans. Roy. Soc. S. Africa, vol. 32, pp. 113-123, 1949.

A rich phytoplankton development occurs in early spring (Aug.) followed by smaller maxima in early summer and autumn. Chaetoceros species and neritic forms predominate. The variation was correlated with hours of sunshine, surface temperature and winds. Violent short-period fluctuations probably result from rapid changes in water-masses due to local wind conditions. In samples collected in Feb., 532-calories were contained in 1 cu. m. of sea water. (Gordon Gunter).

Fritsch, F. E.
Algae and calcareous rocks, The Advancement of Science, vol. 7, No. 25, pp. 57-62, 1950.

Issac, Wm. Edwyn
Studies of South African seaweed vegetation. II. South Coast: Rooi Els to Gansbaai, with special reference to Gansbaal, Trans. Roy. Soc. S. Africa, vol. 32, pp. 125-160, 1949.

Pringsheim, Ernest G., and Pringsheim, Olga
The growth requirements of Porphyridium cruentum, with remarks on the ecology of brackish water algae, Jour. Ecol., vol. 37, pp. 57-64, 1949.

P. cruentum, up to not cultivated only with difficulty, thrives healthily when at least 25% of sea water is added to a mineral agar medium. The ecological and physiological implications of this phenomenon are discussed and other instances are recorded in which algae, living far from the sea, are favored by an admixture of sea water. (Gordon Gunter).

Richardson, Eugene S.
Some Lower Huronian stromatolites of northern Michigan, Fieldiana-geology, vol. 10, No. 8, pp. 47-62, 1949.

Staples, Lloyd W.
Cubic pseudomorphs of quartz after halite in petrified wood, (abst.), Bull. Geol. Soc. Amer., vol. 60, No. 12, pt. 2, pp. 1945-46, 1949.

Vasconcelos, P.
On the occurrence of algal remains in the ancient rocks of Angola, Amer. Midland Naturalist, vol. 41, No. 3, pp. 695-705, 1949.

Williams, Louis G.
Seasonal alternation of marine floras at Cape Lookout, North Carolina, Amer. Jour. Bot., vol. 35, pp. 682-695, 1948.

The algal flora here is shown to have a different species composition from that of the nearby, intensively studied Beaufort estuary, which is explained by differences of environmental conditions respectively

at these two places. This locality supports a permanent flora in which tropical species predominate, being augmented by an annual winter-spring flora with northern affinities and an annual summer-fall flora with tropical affinities. (Gordon Gunter).

Wilson, Douglas P.

The decline of Zostera marina L. at Salcombe and its effect on the shore, Jour. Marine Biol. Assoc. United Kingdom, vol. 28, pp. 395-412, 1949.

A comparison of photographs taken on the eastern shore of Salcombe Harbor, before and after the disappearance of much of the Z. marina shows that where previously there existed extensive sand banks, stabilized by the growth of this plant,,there has been a lowering of ground level of 2 ft. or more, due to the washing away of the sand where the Zostera has died. Much of the ground is more stony than before and has become largely covered with seaweed attached to the stones. The buried fauna is not as rich as it was and some species previously common are rare or have disappeared. A few small patches of Zostera still survive, but the plants are shorter with narrower leaves than before. On the west side of the harbor there also seems to have been a similar drop in shore level at about low-water mark, spring tides following the disappearance of much of the Zostera, and the buried fauna is also poorer than previously; but for this side no photographs and fewer data are available. On the east side the sand washed away from the old Zostera banks has apparently been carried on to the higher levels to add to sand which has been steadily accumulating there for many years, especially near high-tide mark. Plants of Z. marina now growing at Salcombe reach a height of about 3 ft. (about 90 cm.) in summer and have a maximum leaf width of about 0.25 in. (5-7 mm.), whereas previously the plants were longer, possibly reaching 5 or 6 ft. (150-180 cm.) and had wider leaves. Plants from the estuary of the River Yealm near Plymouth certainly reached a length of 5 ft. or more, prior to 1931, and a calculation from an old photograph indicates that their leaves attained a width of at least 8 mm. Old photographs of Zostera growing on soft mud near Ditch End Cove, about Salcombe Harbor, show short very narrow-leaved plants which may have been Z. hornemanniana. (Gordon Gunter).

Young, Robert B. and Mendelssohn, Edgar

Domed algal growths in the Dolomite Series of South Africa, with associated fossil remains, Trans. Geol. Soc. South Africa for 1948, vol. 51, pp. 53-62, 9 pls., 1949.

Detailed description of 2 extensive bands of algal domes in the lowermost beds of the Dolomite Series (age uncertain, may be Cambrian or even pre-Cambrian). Some of the domes contain trapped sediment, pyroclastic fragments and fossilized organic remains that may represent the higher algae.

PROTOZOANS

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Foraminifera and deep sea stratigraphy, Science, vol. 111, p. 228, 1950.

Asano, Kiyoshi
New Miocene Foraminifera from Japan, Jour. Paleo., vol. 23, No. 4, pp. 423-430, 1949.

Fauré-Fremiet, E.
The ecology of some infusorian communities of intertidal pools, Jour. Animal Ecol., vol. 12, pp. 127-130, 1948.

The Infusorian fauna of the intertidal pools of the Concarneau shore includes about 14 free-swimming species. The study made during low tide of the isolated habitat shows that the composition of this community as well as the relative importance of its component species remain nearly constant, in spite of the fact that most of the water is renewed by every high tide. The apparent stability of the community is maintained in two ways: (a) In most of the observed cases, this stability is probably the result of a kind of balance between the distribution inside and outside the habitat of individuals belonging to eurythermal, euryhyaline and widely spread species. (b) With Strombidium oculatum, this stability is the result of a physiological rhythm preserving the free-swimming individuals from the dispersive action of the tide by enclosing them in a cyst adhering to solid surfaces. (Gordon Gunter).

Fauré-Fremiet, E.
Le rythme de maree du Strombidium oculatum Gruber, Bull. Biol. France et Belgique, vol. 82, pp. 3-23, 1948.

Strombidium oculatum, a swimming Infusoria, can be found in rocky pools in the intertidal zone, on the Atlantic coast of France, near Concarneau. It is highly eurythermal and euryhaline. Its green color is due to symbiotic algae (probably Chlamydomonas). The red spot which gives its name to the species is formed by the accumulation of stigmas from disintegrated algae. The protozoan shows a very distinct biological rhythm. It can be seen swimming in the pools during low tide, but sinks to the bottom and encysts just before the moment when the surging tide submerges its habitat. The cyst adheres to the substratum. This remarkable adaptation enables Strombidium to persist in a biotope periodically washed by the waves. There is only one active and one resting period per day. The cyst formed after 6 hours of free life remains quiescent for 18 hours. This rhythm is maintained for some time (2-3 days) in vitro. The relation between tidal rhythm and cyst-free form alternance is discussed. (Gordon Gunter).

Phleger, Fred B. and Walton, William R.
Ecology of marsh and bay Foraminifera, Barnstable, Mass., Amer. Jour. Sci., vol. 248, No. 4, pp. 274-294, 1950.

Van Voorthuysen, J. H.
Recent indigenous and Upper-Cretaceous derived Foraminifera of the Netherlands tidal flats (Wadden), Koninklijk Nederlandsch Aardrijkskundig Genootschap, Tweede Reeks, Deel LXVII, No. 3, pp. 349-353, 1950.

## SPONGES

Burton, Maurice
Ecology of sponges, Nature, vol. 162, pp. 73-74, 1948.

Only exceptionally are sponges found above midtide level. They do not survive much desiccation. Apparent regeneration after short exposure is usually temporary. The nudibranchs and the gastropods, Patella and Littorina eat them. The richest sponge fauna is in the zone of low-water spring tide. (Gordon Gunter).

de Laubenfels, M. W.
The sponges of Kaneohe Bay, Oahu, Pacific Science, vol. 4, No. 1, pp. 3-36, 1950.

## COELENTERATES

Bayer, Frederick M.
The Alcyonaria of Bikini and other atolls in the Marshall Group. Part 1: the Gorgonacea, Pacific Science, vol. 3, No. 3, pp. 195-214, 1949.

Field, Louise Randall
Sea anemones and corals of Beaufort, North Carolina, Duke University Marine Station, Bull. No. 5, pp. 1-39, 1949.

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Lange, Frederico Waldemar
Polychaete annelids from the Devonian of Paraná, Brazil, Bull. Amer. Paleo., vol. 33, No. 134, pp. 1-102, June, 1949.

## MOLLUSKS

Evans, Ronald George
The lethal temperatures of some common British littoral molluscs, Jour. Animal Ecol., vol. 17, pp. 165-173, 1948.

Thermal death points were determined on heating at a rate of 1°C/5 min. until 50% of the individuals failed to recover after cooling for one hour. Heat death among the animals in nature is extremely improbable and there is no apparent correlation between thermal death points of the various snails and their vertical zonation along the shore. The survival times of the molluscs at 30°, 35°, and 40°C. were also obtained and showed a safety limit well beyond that to which they would normally be subjected. There is a correlation however when thermal death points are considered in relation to both tidal level and type of habitat. (Gordon Gunter).

Fischer, Alfred G. and Finley, Robert, Jr.
Microstructure of some Pennsylvanian Nautiloids, (abst.), Bull. Geol. Soc. Amer., vol. 60, No. 12, Pt. 2, p. 1887, 1949.

Fretter, V., and Graham, A.
Feeding and reproduction in the pyramidellids, Nature, vol. 163, No. 4140, pp. 361-362, 1949.

Fretter, V. and Graham, A.
The structure and mode of life of the Pyramidellidae parasitic opisthobranchs, Jour. Mar. Biol. Assoc., United Kingd., vol. 28, No. 2, pp. 493-532, 1949.

Gunter, Gordon
The generic status of living oysters and the scientific name of the common American species, Amer. Midland Naturalist, vol. 43, No. 2, pp. 438-449, 1950.

Kawaguti, Siro
Observations on the Heart Shell, Corculum cardissa (L.) and its associated Zooxanthellae, Pacific Science, vol. 4, No. 1, pp. 43-49, 1950.

Mattox, N. T.
Studies on the biology of the edible oyster, Ostrea rhizophorae Guilding, in Puerto Rico, Ecol. Mongr., vol. 19, pp. 339-356, 1949.

Hydrographic and biological studies were made on the environment of O. rhizophorae living attached to mangrove roots in lagoons around Puerto Rico. Over an 18 months period water temp. varied from 25° to 31°C; $O_2$ variation was 3.9 ppm. to 7 ppm.; pH varied from 7.4 to 8.2, and the salinity varied from 32.9°/oo to 44.02°/oo. Growth studies were made; rate of growth was 0.25 mm. per day for young oysters. This species is dioecious. The oysters are sexually active during all seasons. Setting of spats was observed throughout the entire year. Of 238 individuals sexed, 131 were females and 107 males. Commercial aspects were surveyed. (Gordon Gunter).

Stewart, Roscoe E. and Stewart, Katherine C.
Local relationships of the Mollusca of the Wildcat coast section, Humboldt County, Calif., Oregon Dept. Geol. and Min. Industries, Bull. 36, pt. VIII, pp. 169-208, 1949.

Sullivan, Charlotte M.
Bivalve larvae of Malpeque Bay, P.E.I., Fish Res. Bd. Canada Bull., vol. 77, pp. 1-36, 1948.

Twenty-two species of bivalves occur regularly in the bay. A figure showing seasonal occurrence, and changing abundance relative to water temperatures of the principal species is given. Certain distributional problems are discussed. (Gordon Gunter).

Van Straaten, L. M. J. U.
Environment of formation and facies of the Wadden Sea sediments, Koninklijk Nederlandsch Aardrijkskundig Genootschap, Tweede Reeks, Deel LXVII, No. 3, pp. 354-368, 1950.

Watson, Hugh
A note on Bathonian gastropods assigned to freshwater genera, Geol. Mag., vol. 87, No. 1, pp. 17-25, 1950.

Yonge, C. M.
On the structure and adaptations of the Tellinacea, deposit-feeding Eulamellibranchia, Phil. Trans. Royal Soc. London, Ser. B., vol. 234, No. 609, pp. 29-76, 1949.

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Gill, Edmund D.
A new trilobite from the Yeringian (Lower Devonian) rocks of Kinglake, Victoria, Proc. Royal Soc. Victoria, vol. 59, pt. 1, pp. 8-19, 1947.

Rothwell, W. Thomas, Jr.
Preliminary report on Ostracoda in bottom samples and cores of northwestern Gulf of Mexico, (abstract), Bull. Geol. Soc. Amer., vol. 60, No. 12, pt. 2, p. 1918, 1949.

## VERTEBRATES

Bock, Wilhelm
Triassic chimaeroid egg capsules from the Connecticut Valley, Jour. Paleo., vol. 23, No. 5, pp. 515-517, 1949.

Jensen, Aage J. C.
Hestemakreler, Kuller og. Glyse i den vestige Osterso og det sydlige Baelthav. (Horse mackerel, haddock and poor cod in the western Beltic and the southern part of the Belts.), Dansk Fiskeritidende, vol. 66, pp. 63-66, 1948.

Normally all three species are rather rare in the inner Danish waters but in January, 1948, hugh quantities of horse mackerel, 10-14 cm. long, were cast ashore in up to 0.5 m. thick layers at some places

here. Obviously they had been carried into these waters by a strong inflow in Aug.-Sept. and were killed by the cold. Also more than normal numbers of haddock, poor cod and whiting were found in these waters in the latter half of 1947. (Gordon Gunter).

## PROBLEMATICAL FOSSILS

Faul, Henry

Fossil burrows from the Pre-Cambrian ajibik quartzite of Michigan, Nature, vol. 164, p. 32, 1949; also Jour. Paleo., vol. 24, No. 1, pp. 102-106, 1950.

Rankama, Kalervo

Corycium resuscitatum: a discussion, Jour. Geol., vol. 58, No. 1, pp. 75-79, 1950.

# ANNOTATED BIBLIOGRAPHY ON THE ECOLOGY OF MARINE BACTERIA[1/]

by

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Bacteria, yeasts, molds, and allied microorganisms of many physiological types are widely distributed in the sea. They are particularly abundant in bottom deposits where they influence the diagenesis of sediments in many ways. By virtue of their ecological versatility, their ready adaptability to various environmental conditions, their rapidity of multiplication under favorable conditions, and their ability to catalyze reactions involving nearly all kinds of organic compounds as well as several inorganic compounds, marine bacteria are important biochemical, geological, and hydrobiological agents. Bacteria affect the abundance of other organisms in the sea by producing plant nutrients, by competing for dissolved oxygen, by serving as a source of food for numerous genera of animals, by affecting physicochemical conditions in localized regions, and by infecting both plants and animals.

The numbers of bacteria found in sea water, as determined by plating procedures which detect only a small percentage of viable cells, range from a few cells to hundreds of thousands of cells per ml. The numbers and kinds of bacteria in the sea is influenced by the organic content of water, the presence of suspended solids to which bacteria can attach, the occurrence of other organisms, and a multiplicity of other interrelated factors. While temperature effects the rate of bacterial activities, it seems to have only an indirect affect upon the distribution of bacteria in the sea. Neither low temperatures nor high hydrostatic pressures, characteristic of the deep sea, restricts the bacterial population. The low concentration of organic matter appears to be the principal factor that limits the bacterial population, a condition which is indicative of the efficiency of bacteria in destroying organic matter in the sea.

In the open ocean the abundance of bacteria increases from the surface downward to depths of forty or fifty meters and then gradually decreases until the bottom is reached where there may be millions of viable cells per ml. at the mud-water interface. It is not uncommon to find hundreds of millions per gram of mud or enough to give from 0.3 to 2 mgm. of living bacteria per gram (dry basis).

Wherever profile series have been examined, a progressive decrease with depth has been observed in the bacterial population of bottom deposits. Appreciable numbers of living bacteria have been detected, however, in the

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bottom of the longest cores examined, viz. 800 cm. Some of the latter from the deep sea represent a geological age exceeding 100,000 years. Decreases with depth in the organic content and changes in its composition, as well as changes in other chemical properties of the mud attributable to bacteria, indicate that the bacteria have been active. The extrapolation of curves depicting the vertical distribution of bacteria in marine bottom deposits indicates that living bacteria might be found at depths of several hundred meters. Actually, living bacteria have been found in cores of ancient marine sediments from sulfur and oil wells from depths as great as 2,000 meters. The greatest depth at which bacteria can live in sediments is probably determined primarily by the availability of nutrients.

The demonstrated ability of bacteria to produce and modify certain hydrocarbons suggests that they may play a part in the origin of oil. By their tendency to alter the hydrogen-ion concentration, to utilize or produce carbon dioxide, and to destroy organic compounds of calcium, bacteria in sediments may influence the precipitation or dissolution of calcium carbonate. They affect the state of sulfur, iron, manganese, hydrogen, and other elements in sediments in various ways. Bacteria are believed to be the principal dynamic agents that influence the redox potential of marine sediments.

The following annotated bibliography has been selected from nearly a thousand published papers dealing with the occurrence, activity, and importance of bacteria in the sea.

Allen, Esther C. See ZoBell, C. E., 9

Anderson, D. Q. See also ZoBell, C. E., 10, 11.

1. Distribution of organic matter in marine sediments and its availability to further decomposition: Jour. Mar. Res., vol. 2, pp. 225-235, 1940.

All of 158 samples of marine bottom deposits examined were found to contain bacteria that decomposed organic matter. The mud samples came from 35 to 43° N. Lat. and from 67 to 70° W. Long. from water depths ranging from a few meters to 5,100 meters. Oxygen consumption was employed as the criterion of bacterial activity.

Angst, E. C.

1. Some new agar-digesting bacteria: Puget Sound Biol. Sta., Univ. Wash. Publ., vol. 7, pp. 49-63, 1929.

Description and key for 13 new species of agar-splitting bacteria isolated from coastal water and from the surface of fronds of red and brown algae in the Puget Sound region. All were assigned to the genus Agarbacterium. The bacteria were not parasitic on the algae but appeared to be harmless epiphytes or saprophytes.

Baas-Becking, L. G. M.

1. Studies on the sulfur bacteria: Ann. Botany, vol. 39, pp. 613-650, 1925.

Bacteria that oxidize hydrogen sulfide and other forms of sulfur occur most abundantly in regions where water is relatively rich in organic matter. In natural waters most of the hydrogen sulfide required by sulfur bacteria is believed to come from the bacterial reduction of sulfate. Good review on ecology and physiology of sulfur bacteria, including 68 references.

2. On organisms living in concentrated brine: Tijdsch. Ned. Dierk. Ver., vol. 1, no. 1, pp. 6-9, 1928.

Chart showing kinds of bacteria, fungi, blue-green algae, and protozoa found in marine salterns and other concentrated brines.

Baier, C. R.

1. Studien zur Hydrobakteriologie stehender Binnengewasser: Arch. f. Hydrobiol., vol. 29, pp. 183-264, 1935.

Although concerned primarily with the occurrence and activity of bacteria and allied microorganisms in lakes, estuaries, and brackish waters, there is much information in this paper that is directly applicable to problems of marine ecology. Particularly significant is the chapter on the relationship between fauna and microflora of water. The bibliography of 157 references includes titles. There is an English translation of this treatise at the Scripps Institution, La Jolla.

2. Untersuchungen zur Hydrobakteriologie norddeutscher Seen mit Kalk- und Humusgehalt: Die Naturwessenschaften, vol. 24, pp. 469-473, 1936.

Bacteria in North-German seas contribute to lime and humus content.

3. Die Bedeutung der Bakterien für den Kalktransport in der Gewässern: Geol. d. Meere u. Binnengewässer, vol. 1, pp. 75-105, 1937.

Bacteria promote calcium carbonate precipitation in shallow seas (a) by producing carbon dioxide, (b) by increasing the pH, and (c) by decomposing organic compounds of calcium. Article includes 129 references.

4. Chemisch-mikrobiologische Beobachtungen zur Sedimentdiagenese an postglazialen Sedimenten der Eckernförder Bucht (Ostsee): Geol. Rundschau, vol. 29, pp. 316-321, 1938.

Anaerobic bacteria and filamentous forms found in post-glacial sediments to a depth of 11.8 meters. Changes with depth in the carbonate, sulfate, and sulfur content of the sediments suggests that the bacteria have been active in reducing sulfur and decomposing organic matter.

Ballantyne, E. M.

1. On certain factors influencing the survival of bacteria in water and saline solutions: Jour. Bact., vol. 19, pp. 303-320, 1930.

Besides being affected by the salinity or osmotic pressure of water, the survival of bacteria is influenced by the organic content, temperature, light (in upper layers), pH, oxygen tension, and other factors. 26 references.

Baranik-Pikowsky, M. A.

1. Über den Einfluss höher Salzkonzentrationen auf die Limanbakterien: Centralbl. f. Bakt., II Abt., vol. 70, pp. 373-383, 1927.

Descriptions of several species of marine bacteria isolated from limans near Odessa, where the salt concentration sometimes reached 25.6 o/oo. Numerous species of denitrifiers and sulfide producers present.

Barghoorn, E. S.

1. (and Linder, D. H.). Marine fungi: their taxonomy and biology: Farlowia, vol. 1, pp. 395-467; 1944.

Descriptions of seven species of marine fungi isolated from decomposing cordage fibre and wood submerged in salt or brackish water. Organisms grew readily in sea water at temperatures ranging from 5° to 27.6° C. Adapted to grow in sea water three times normal salinity. 45 references.

Bartholomew, J. W.

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Bacteria that multiply at 60°C. but not at 20° or 37°C. isolated from top, middle, and bottom of 50 and 70 inch cores of mud collected aseptically from the sea floor 30 miles offshore where the water was 2,880 to 4,320 feet deep.

Bastin, E. S.

1. The problem of the natural reduction of sulphates: Am. Assoc. Petroleum Geologists Bull., vol. 10, pp. 1270-1299, 1926.

Sulfate-reducing bacteria detected in several samples of ancient marine sediments, such bacteria being present in 28 out of 30 Illinois oil wells and in 15 out of 37 California oil wells at depths ranging from 760 to 2,500 feet.

Baur, E.

1. Ueber zwei denitrificirande Bakterien aus der Ostsee: Wiss. Meeresunters., Abt. Kiel, N. F., vol. 6, pp. 9-22, 1902.

Denitrifying bacteria demonstrated in Kiel Bay. Bacillus actinopelte described.

Bavendamm, W.

1. Die farblosen und roten Schwefelbakterien des Süss- und Salzwassers: G. Fischer, Jena, 159 pages, 1924.

A monographic treatment on the occurrence and activity of sulfur bacteria in fresh and salt water. 295 references, mostly with titles.

2. Die mikrobiologische Kalkfällung in der tropischen See: Arch. f. Mikrobiol., vol. 3, pp. 205-276, 1932.

Detailed discussion of sulfur-oxidizing, agar-splitting, cellulose-decomposing, urea-fermenting, sulfate-reducing, nitrogen-fixing, and other physiological types of bacteria found in the sea in the Bahama Island region, with particular reference to their role in the precipitation of calcium carbonate. 143 references.

Bedford, R. H.

1. Marine bacteria of the northern Pacific Ocean. The temperature range of growth: Canad. Biol. Fish. Contr., N. S., vol. 7, pp. 431-438, 1933.

Optimum temperature for the growth of 71 cultures of marine bacteria was 20° to 25°C. Minimum for 10 was -7.5°C., -5°C. for 12, 0°C for 53, 5°C. for 2, 10°C. for 3, and minimum for one was 15°C. Maximum temperatures for growth were as follows: 5 at 25°C., 36°at 30°C., 13 at 37°C., 5 at 40°C., 2 at 42.5°C., and 4 at 45°C. All were killed at 50°C.

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1. Bacteriologie des Meeres: Abderhalden's Handb. d. biol. Arbeitsmethoden, IX Abt., vol. 5, pp. 717-854, 1933.

Review of literature on the distribution and activity of bacteria in the sea, with 600 references.

Berkeley, C.

1. A study of marine bacteria, Straits of Georgia, B. C.: Roy. Soc. Canada Trans., Ser. 3, Sect. 5, vol. 13, pp. 15-43, 1919.

No nitrifiers or denitrifiers found among the many bacteria demonstrated in sea water. Most marine bacteria appear to be polymorphic, motile, halophilic, and sensitive to temperatures exceeding 40°C.

Bertel, R.

1. Sur la distribution quantitative des bactéries planctoniques der côtes de Monaco: Inst. Oceanogr. Bull., Monaco, No. 224, pp. 1-12, 1912.

High bacterial population in Atlantic Ocean between the Azores and Portugal attributed to submarine ridge with a rich fauna. Number of bacteria in water diminished with distance from land.

2. Les bactéries marines et leur influence sur la circulation de la matiere dans la mer: Inst. Oceanogr. Bull. Monaco, No. 672, pp. 1-12, 1935.

Among the physiological types of bacteria found in the sea were sulfate reducers, chitin decomposers, urea fermenters, light producers, and ammonia formers.

Bogdanova, I. See Butkevich, V. S., 5.

Brannon, M. A.

1. The action of Salton Sea water on vegetable tissues: Carnegie Inst. Wash., Publ. No. 193, pp. 71-78, 1914.

Species of Amylobacter, Beggiatoa, Spirillum, and other bacteria found in woody plants undergoing decomposition in the Salton Sea.

Brandt, K.

1. Stickstoffverbindungen im Meere: Wiss. Meeresunters., Abt. Kiel, N. F., vol. 20, pp. 203-292, 1927.

Nitrifying bacteria demonstrated in bottom waters of open sea and inshore waters of North and Baltic Seas, but none in upper strata of open seas.

Brebeck, C. See Fischer, B., 5.

Burgess, W. T. See Frankland, E., 1.

Burke, V.

1. The interchange of bacteria between fresh water and the sea: Jour. Bact., vol. 27, pp. 201-205, 1934.

Fresh water bacteria may be acclimatized to grow in sea water, but salt concentration may affect their characteristics.

Burgwitz, G. See Nadson, G., 1.

Butkevich, V. S.

1. Die Bildung der Eisenmangan-Ablagerungen am Meeresboden und die daran beteiligten Mikroorganismen: Ber. d. wiss. Meeresinst., Moscow, vol. 3, No. 3, pp. 5-81, 1928. (In Russian with German summary).

Iron concretions in White Sea attributed to bacterial activity. In the White Sea were found bacteria which oxidize iron and manganese. Described two new species, Gallionella tortuosa and G. reticulosa. 86 references.

2. Zur Methodik der bakteriologischen Meeresuntersuchungen und einige Angaben über die Verteilung der Bakterien im Wasser und in den Böden des Barents Meeres: Oceanogr. Inst. Moscow, Trans., vol. 2, pp. 5-39, 1932. (In Russian with German summary).

Factors influencing the distribution and physiological activities of bacteria in water and bottom deposits of the Barents Sea. Estimated topmost 4 cm. of sea bottom to contain 20 grams of bacteria per square meter. Some bacteria developed at -3° to -7° C.

3. Bacteria in the seas of the high latitude Arctic regions: Compt. rend. Acad. Sci. USSR, vol. 19, pp. 651-652, 1938.

Bacteria in a cubic kilometer of Arctic water at 83° N. Lat. estimated to make a mass of 3.5 to 7 tons. Abundance of bacteria increased from surface down to 100 meters where there were around 10,000 per ml. as indicated by plate counts.

4. On the bacterial population of the Caspian and Azov Seas: Mikrobiologiia, vol. 7, pp. 1005-1021, 1938. (In Russian with English summary).

Biomass of bacteria believed to be about the same as that of phytoplankton in the Caspian Sea, 500,000 bacteria per ml. being equivalent to a biomass of 250 mgm. per cubic meter. Several physiological types of bacteria found in bottom slime of Caspian and Azov Seas.

5. (and Bogdanova, I.). Some specificities of the bacterial population of Arctic seas: Mikrobiologiia, vol. 8, pp. 1073-1095, 1939. (In Russian with English summary).

Bacteria isolated from Kara Sea differed from those from other marine environments.

Butler, Margaret R. See Waksman, S. A., 6

Carey, Cornelia, L. See also Waksman, S. A., 4, 5.

1. The occurrence and distribution of nitrifying bacteria in the sea: Jour. Mar. Res., vol. 1, pp. 291-304, 1938.

Most bottom samples showed presence of nitrifiers, but only a few 500 ml. samples of water showed nitrite formation from ammonium. Nitrifiers also found associated with plankton tows.

Certes, A.

1. Note relative a l'action des hautes pressions sur la vitalité des micro-organismes d'eau douce et d'eau de mer: Compt. rend. Soc. Biol., vol. 36, pp. 220-222, 1884.

Marine microorganisms more resistant to pressure than fresh water forms.

2. Sur la culture, a l'abri des germes atmospheriques, des eaux et des sediments rapportes par les expeditions du Travailleur et du Talisman; 1882-1883: Compt. rend Acad. Sci., vol. 98, pp. 690-693, 1884.

Bacteria demonstrated in all except 4 out of 100 samples of water collected on the TALISMAN Expedition, some samples coming from depths as great as 5,000 meters. Bacteria also present in air over the ocean.

Conn, Jean E. See ZoBell, C. E., 12.

Copenhagen, W. J.

1. Occurrence of sulphides in certain areas of the sea bottom on the South African coast: Union So. Africa Fish Mar. Biol. Survey, Report No. 3, pp. 3-18, 1934.

Sulfate-reducing bacteria in Walvis Bay believed to account for concentrations of hydrogen sulfide sometimes lethal to fauna and flora.

Daniels, L. L. (Daines, L. L.)

1. On the flora of Great Salt Lake: Amer. Naturalist, vol. 51, pp. 499-506, 1917.

From Great Salt Lake were isolated 5 species of bacteria that grew in media containing 25% NaCl.

Daniltchenko, P.

1. (and Tschigirine, N.). Sur l'origine de l'hydrosulfure dans la mer Noire: Trav. du La. zool. et de la Sta. biol. de Sébastopol, Ser. 2, No. 10, pp. 141-191, 1926.

Absence of oxygen in Black Sea below 170 to 200 meters attributed to action of sulfate-reducing and other bacteria.

Dianova, E. See Voroschilova, A., 1.

Drew, G. H.

1. The action of some denitrifying bacteria in tropical and temperate seas, and the bacterial precipitation of calcium carbonate in the sea: Jour. Mar. Biol. Assoc., vol. 9, pp. 142-155, 1911.

Bacterial flora of English Channel abundant and varied due to terrestrial contamination. Denitrifiers abundant in tropical waters near Jamaica and Tortugas.

2. Report of investigations on marine bacteria carried on at Andros Island, Bahamas, British West Indies, in May, 1912: Carnegie Inst. Wash. Yearbook, No. 11, pp. 136-144, 1912.

Bacteria decreased in abundance from surface to 800 fathoms until bottom reached where mud contained average of 160,000,000 per ml. Destruction of nitrates and nitrites by denitrifiers around West Indies thought to account for scarcity of phytoplankton.

3. On the precipitation of calcium carbonate in the sea by marine bacteria, and on the action of denitrifying bacteria in tropical and temperate seas: Jour. Mar. Biol. Assoc., vol. 9, pp. 479-524, 1913.

Marine bacteria which promote precipitation of calcium carbonate around the Bahama Islands are quite sensitive to heat and to heavy metals.

Elazari-Volcani, B.

1. Studies on the microflora of the Dead Sea: Hebrew University, Jerusalem, Dissertation, 119 pages, 1940. (Hebrew with English summary).

Although the water is virtually saturated with salt, many types of bacteria live in the Dead Sea. 85 references.

2. Bacteria in the bottom sediments of the Dead Sea: Nature, vol. 152, pp. 274-275, 1943.

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Eyre, J. W. H.

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Occurrence and activity of denitrifying bacteria in the Baltic Sea.

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Description of 14 bacterial species from Kiel harbor, capable of growing at 0°C.

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Observations on bacterial population of water samples collected from different depths during the South Polar Expedition, including a good review of early literature on marine bacteriology.

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Numerous bacteria found in slime of live haddock.

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Isolated 15 species of Micrococcus, 5 Pseudomonas, 1 Eberthella, 18 Flavobacterium, 31 Achromobacter, 5 Bacillus, 2 Proteus, and 1 Serratia species from slime and feces of 43 marine fish representing 11 species.

2. Lactose-fermenting bacteria from the intestinal contents of marine fish: Canad. Biol. Fish. Contr., N. S., vol. 8, pp. 291-300, 1934.

Microflora of offshore fish differs from that isolated from fish taken near shore, suggesting contamination.

Gietzen, Johanna

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Occurrence and characteristics of sulfur bacteria in the sea, including a bibliography with 97 references.

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Many bacteria found in muds from the Black Sea at depths of 260 to 1900 meters. Organic matter converted into petroleum-like substances.

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Review of literature on number and kind of bacteria found associated with marine fish. 62 references.

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Temperature range of growth of marine bacteria, including bibliography of 40 references.

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Chitin-digesting bacteria isolated from live lobsters.

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Chitin-digesting bacteria isolated from marine sands, mud, water, crabs, and from several mollusks.

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Salmon spoilage bacteria identified as being the same as those commonly found in sea water.

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Sulfate-reducing bacteria in the Black Sea.

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Nitrifying, urea-fermenting, sulfate reducers, putrefactive, and other physiological types of bacteria found in the Kara Sea north of 80° 25' N. Lat. In the bottom mud many millions were found per gram, unevenly distributed in clumps or zoogiea.

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Azotobacter and other nitrogen-fixing bacteria found near shore.

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Fungi parasitic on marine algae.

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Bacteria from fresh water survive only a short time in the sea.

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In the summer when shallow waters become very saline all except spore-forming bacteria perish owing to high salinity. Fresh water bacteria are more resistant to changes in osmotic pressure than marine forms.

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Azotobacter-like bacteria which fix no nitrogen found in the sea.

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Until it is boiled water from Black Sea is sufficiently bactericidal to inhibit the growth of many fresh water species.

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Bacterial population of Chukostkoie and East Siberian seas.

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Bacteria found in water from melted ice as well as in water collected from a depth of 2,700 meters in the Arctic Ocean.

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Lipman, C. B.

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No nitrifying bacteria found in water from open oceans, but such microbes occur in marine bottom deposits.

2. A critical and experimental study of Drew's bacterial hypothesis on $CaCO_3$ precipitation in the sea: Carnegie Inst. Wash., Dept. Mar. Biol., vol. 19, pp. 179-191, 1924.

Production of ammonia from decomposition of organic matter believed to be the most important factor in the bacteria precipitation of calcium carbonate. Hundreds of thousands of bacteria detected per ml. of near-shore water off Samoa, but bacterial numbers very small in the open sea.

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Diluting sea water with one volume of fresh water inhibits the growth of many marine microorganisms, further dilution being progressively more inimical.

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Questions whether there are enough bacteria in waters of open seas to affect the precipitation of calcium carbonate.

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Abundance of bacteria in Clyde Sea believed to be influenced by sunlight, temperature, water movements, sedimentation, terrigenous pollution, and biological factors.

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Several varieties of agar-splitting bacteria found along the Norwegian coast; 7 new species described. 19 references.

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Bacteria, actinomyces, and yeast which promote calcium carbonate precipitation in the sea.

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Red Torula, black Mycoderma, and other yeast found in the sea.

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Bacteria found at different depths in Atlantic Ocean between Germany and Brazil.

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Living bacteria found in gut of echinoderms taken from a depth of 4,000 meters.

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Vertical distribution of bacteria in the Atlantic Ocean to depths of 6,000 meters.

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Wasting disease of eel grass attributed to fungi.

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Bacteria do not compete with phytoplankton for phosphates in the sea, because phosphates are quickly regenerated from bacterial cell substance.

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Movements of air masses play an important part in the interchange of microorganisms between the soil and sea.

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Large numbers of bacteria found in marine bottom deposits, some found in cores 330 cm. long.

Rodionowa, K. See Ginsburg-Karagitscheva, T., 1, 2.

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Abundance of bacteria in waters of Gulf of Naples decreases from the surface downward until bottom is reached where largest microbial populations occur. Count decreases with distance from land. Seven new species described.

2. Bacterial investigation of the sea and its floor: Botan. Gaz., vol. 17, pp. 312-321, 1892.

Comparison of the ecology, physiology, and morphology of bacteria found in water and bottom deposits in the Woods Hole region and in the Gulf of Naples.

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More bacteria in mud or slime than in overlayering water. Aerobic bacteria predominate in abundance.

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Bacteria isolated from fish caught in Atlantic Ocean at depths of from 30 to 60 fathoms.

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A morphologically diverse microbial flora found to be indigenous to Great Salt Lake.

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Eighteen species of fungi found growing as parasites or saprophytes on various marine algae in the Woods Hole region.

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Several species of fungi found associated with decaying phytoplankton in the Woods Hole region.

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Tschigirine, N. See Daniltchenko, P., 1.

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Abundance of bacteria in the sea influenced by relationships with other organisms, temperature, nutrients, and several other ecological factors.

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Nannoplankton believed to limit bacterial population in the sea.

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Review of literature on temperature tolerance of marine bacteria. 38 references.

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Numbers, kinds, physiological activities, and distribution of bacteria in marine sediments.

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Marine bacteria carried long distances by the movements of air masses. Terrestrial bacteria found in air over the ocean.

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A review article on the ecology of marine bacteria and their importance in the economy of the sea.

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Factors influencing the distribution and physiological activities of bacteria in the sea, including an index of the named species. 161 references.

# STRONTIUM BIOGEOCHEMISTRY, ECOSYSTEMS, AND PALEOECOLOGICAL TOOLS[1]

by

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A detailed study of the strontium cycle has two contributions to make to paleoecology as follows:

First, the past pattern of strontium behavior may be discovered as an end in itself, since one of the aims of Paleoecology[2] is the elucidation of the interactions of chemical as well as biological and geological entities.

Second, since the distribution of strontium is related to other natural pheonomena by known principles, analyses of strontium in the fossil record can be used as tools to infer past phenomena.

In the present study, analyses of strontium are being made in wide coverage of the major types of matter in the biosphere. These analyses, usually handled as Sr/Ca ratios, are being studied to determine the principles of distribution of strontium especially in relation to calcium.

A quantitative cycle for strontium is being constructed. The amount of flow relative to calcium has been roughly calculated for the path from magma to crystalline rocks, to waters, to sea, to sediments, and to magma or to waters again. A slight amount circulates in the atmosphere. The total flux of strontium through the ocean is about $32 \times 10^{11}$ grams per year.

It is proposed as a general law that in any system of successive processes in which the quantity at one stage depends on the quantity in the preceding stage, the whole system seeks a steady state. If the concentration at one stage gets smaller, the transfer of material from this stage to the next slows down until the concentration in the low stage increases to its normal level again. Because systems of this type have a self correcting mechanism, they are retained by process of elimination. We may thus conclude that world ecosystems seek conditions that are self balancing and in which the flux is dependant on the concentrations in the successive stages. To state this in another way, natural selection retains systems

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1/ Notes from a dissertation presented to the Faculty of Yale University in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

2/ One of the modern viewpoints defines ecology as the study of principles relating world units at the earth or natural level of integration. It is the study of large complex units or ecosystems which include both organic and inorganic components.

and complexes, organic or inorganic, which have selfbalancing mechanisms. Natural selection as a concept may be applied accurately to any time succession of possible alternatives.

The rate of entrance of strontium from one stage to another has been shown to depend on the concentration in the previous stage. Thus strontium in minerals reflects the magma concentration, strontium in waters reflects the concentration in the drainage area, strontium in sediments reflects the concentration in the waters, strontium in carbonate and phosphatic organic and inorganic precipitates reflects the aqueous medium, etc. The establishment of these facts leads to the important conclusion that the concentrations and Sr/Ca ratio are conservative and that the whole cycle approaches a steady state.

The Sr/Ca ratio of a skeleton has been shown to be a function of the Sr/Ca ratio of the aquatic medium both in laboratory cultures and in nature. Therefore it is possible by analyzing fossils to infer the Sr/Ca ratio of the past oceans. This has been done on selected materials and it is possible to conclude that the Sr/Ca ratio has not been much different since at least early in the Paleozoic[3/]. The evidence prior to the Paleozoic is inadequate because unaltered fossil material is non existant and inferences from Sr/Ca ratio in limestones are misleading.

Since the ocean dominates the world strontium cycle, it is inferred that the world strontium cycle has been in a steady state for a long time. Thus the strontium cycle is a substantiated case that fits the theory of steady states mentioned above. The strontium cycle may therefore properly be considered an ecological entity, a complex, and an ecosystem using these terms synonomously in this application.

Because of the intimate correlation of the alkaline earth cycles with other geochemical cycles, considerable doubt is cast upon the supposed transitory nature of other cycles, neglecting minor fluctuations. Even the sodium system, that is usually visualized as continually going toward higher concentrations in the ocean must be studied carefully. If sodium increases continually, eventually the state will be reached at which time the amount of sodium leaving the sea by atmosphere, sediments, and evaporites balances the amount returning to the sea by rivers. This will be the case since ecosystems seek concentration dependant processes. It is just possible that it is in balance now especially since the igneous component of drainage to the sea is very small because of the blanket of sediments over much of the continents.

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3/ An attempt by Dieulafait in 1877 to infer the nature of past oceans from the presence of strontium in Paleozoic Brachiopods preceded the present study by seventy years. The pioneer note by Dieulafait is one of the first contributions to paleochemistry and until recently has been completely overlooked by most people including the author. The shortening of the very long title in bibliographies was misleading because it did not suggest the attempted line of reasoning that was in the note.

Dieulafait, L. 1877

La Strontiane, sa diffusion dans la nature minerale et dans la nature vivante, a l'epoque actuelle et dans la serie des temps geologique. Consequences relatives aux minerales saliferes. Compt Rendu Acad. Sci. 84, p. 303.

The distribution factor for Sr/Ca ratio in skeletal deposition is of the order of 1--5 and negative. That is, the ratio decreases by a factor of 1 to 5 times between the medium and the skeleton. The distribution factor is characteristic for given species and has been shown to be partly a function of mineralogical form and partly a function of the organism's physiology.

The distribution factor for replacement and recrystallization is also negative as in the case of intial deposition. Consequently the Sr/Ca ratio of fossils is generally the same as the modern fossils or lower and as a result replacement can be detected. In fact the distribution factor is a measure of the degree of replacement and recrystallization. Dolomites have very low Sr/Ca ratios except where the strontium which did not enter the lattices formed celestite crystals. The Sr/Ca ratios in cores from Bikini and Funafuti show a contrast between high values for unaltered materials and very low values for altered and dolomitized materials.

The Sr/Ca ratios of skeltons and sediments of closed basins are higher than the Sr/Ca ratios in the skeltons and sediments of open lakes and rivers because of the negative distribution factor between Sr/Ca of the water and the Sr/Ca of the skeletons and sediments. In closed lakes all Sr and Ca must necessarily go into the sediments since there is no other outlet for non volatile constituents. In the process the Sr/Ca ratio of the water is kept at a higher steady level. The Sr/Ca of the sediments thus equals the Sr/Ca of the inflowing water. In open basins the Sr/Ca of the water is not much raised because the carbonate precipitation which raises the Sr/Ca of the water in the case of closed basins is not as predominant as the inflow of water with constant ratio. The strontium that is left in the water relative to the calcium during carbonate precipitation does not accumulate but flows through the outlet. Thus the waters have the same Sr/Ca of the drainage and the sediments a lower Sr/Ca ratio. These differences between closed and open basins make it possible to use the Sr/Ca ratio of sediments and fossils as a tool to tell whether a deposit was from an open or closed basin. The Sr/Ca ratio of the sediments is a function of the inflow/outflow ratio and thus of the climate. If the deposit is known to be a lake deposit and not marine, the aridity of the climate may be inferred.

These tools have been used on some classical formations with interesting results. For example, a low Sr/Ca ratio for the Solenhofen limestone suggests a freshwater origin if there was no replacement. Whereas most of the localities agree with expected conditions from geological evidence, there strange one as in the case of the high Sr/Ca ratio of an Ostracoderm Bothryolepis. This might suggest a marine or salt lake condition. However, the deposit might be one of the few known localities with the very high Sr/Ca ratio due to unusual geological conditions which have concentrated strontium minerals. For example the fossil teeth and bone of the Jurassic Morrison river formation have Sr/Ca ratios twice that of modern marine vertebrates or other fossils. Here the association of high strontium with uranium suggests that the source of the Sr and calcium either before the animals formed the skeletons or in diagenesis was a pegmatite. High Sr/Ca ratios are characteristic of mineralized ground waters and springs which geochemically agrees with the relative removal of strontium in diagenesis.

An example of the use of the Sr/Ca ratio to infer climate is an analysis of algae from the Eocene Green River formation. Here a high Sr/Ca value similar to a modern value from an algae in Lake Winnemucca, Nevada indicates that the lake was closed and the climate was therefore probably arid. Fresh water calcareous algae and calcareous sediments from humid regions generally have low Sr/Ca ratios.

There are other paleoecological tool possibilities such as inferring something on diet by Sr/Ca ratios in cases where an animal gets its Sr/Ca ratio from its food. There may be other uses for the Sr/Ca ratio that further work will disclose.

The conclusion at the present stage of this study so far as it relates to Paleoecology is as follows:

(1) The strontium cycle is a self balancing complex or ecosystem which has been in more or less of a steady state since early Paleozoic time.

(2) The establishment of the strontium cycle as existing in the past with the same principles operating as today makes possible the use of the Sr/Ca ratio as a tool in favorable circumstances for making inferences as to chemistry of ancient habitats, past climates, and the extent of replacement. Inferences may be made about one condition if the other conditions are known from independent evidence.

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